PHILLIPS

Discharge

of

Water Through Submerged

Orifices

Civil Engineering

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DISCHARGE

OF

WATER THROUGH SUBMERGED ORIFICES

BY

GUY DERRICK PHILLIPS

THESIS

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IN

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C O L L E G E   O F   E N G I N E E R I N G

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This is to certify that the following thesis prepared under the direction of Professor A. N. Talbot, Head of Department of Municipal and Sanitary Engineering, by

GUY DERRICK PHILLIPS

entitled DISCHARGE OF WATER THROUGH SUBMERGED ORIFICES

is accepted by me as fulfilling this part of the requirements for the Degree of Bachelor of Science in Civil Engineering.

Ira O. Baker

Head of Department of Civil Engineering

INTRODUCTION.

The subject, DISCHARGE OF WATER THROUGH SUBMERGED ORIFICES, is one upon which but little experimental work has been done as compared with the free discharge of water through orifices into air. It is strange that this should be so considering the number of important uses for submerged orifices. At the present time submerged orifices are used for measuring or estimating the flow of water to and from filter beds, reservoirs, and from canals to power plants. They are often used too, but not as a measuring device, for tide-gates, and for the discharge of waste water through dams.

Previous experiments on this subject have generally been made for the purpose of determining the coefficients of discharge for effective heads of 0.5 ft. or over, but as lower heads than these are very often used there is need for data with low heads.

Some experimentors in this line of work state that the coefficient of discharge for a submerged orifice is the same as the coefficient of discharge for an orifice discharging freely into the air. Others say that the coefficients are from 2% to 5% less than for free discharge. To find which of these two views is correct and to determine the value of coefficients for low heads form the main objects of this thesis.

Experiments of interest along this line were first carried on by James B. Francis in 1854, and again by Hamilton Smith Jr. in 1884.

The order of presentation in this thesis will be as follows:- I. Theory; II. Methods of Experimentation; III. Sources of Error; IV. Plates and Tables; V. Discussion Of Results and Conclusions..

I.

THEORY.

The effective head, or head which causes the flow of water through a submerged orifice, is the difference in level between the water on one side of the orifice and that on the other. This head in producing the discharge is used up in two ways, Ist. by entrance head which relates to the contraction and expansion of the stream, and 2nd. by giving velocity to the stream. The equation which shows the above relation is $h = m\frac{V^2}{2g} + \frac{V^2}{2g}$, or $h = (m+1)\frac{V^2}{2g}$, where h is the head on the orifice, or head causing the flow, $m\frac{V^2}{2g}$ represents the head used up in entrance expansion and losses, and $\frac{V^2}{2g}$ represents the head giving velocity. In the equation V is the average velocity through the orifice in feet per second, g is the acceleration due to gravity, taken as 32.2 ft. per second, and m is the coefficient of loss due to entrance. The term $\frac{V^2}{2g}$ is commonly termed "velocity head". The value for m is obtained from the expression $m = \frac{1}{c^2} - 1$ (See Merriman's Hydraulics, Art.85, 1905 Edition) where c is the coefficient of discharge and is obtained by dividing the actual discharge by the ideal discharge which is $a\sqrt{2gh}$, where a is the area of the orifice.

The value of c may be determined from the equation $c = \frac{q}{a\sqrt{2gh}}$ where q is equal to the actual discharge in cubic feet per second. This equation may be written $c = \frac{q}{8.02a\sqrt{h}}$

In this thesis the value of m which results from the experimental work, has not been calculated. All other members of the equations given have been determined as accurately as possible.

II.

METHODS OF EXPERIMENTATION.

In all the experiments here-in described, the orifices used were made of cast iron plates 1-2 inch thick, with the opening cut out of the center. The orifices tested were of different shapes, some being circular, some square, and still others rectangular. All plates had the orifice hole beveled from one face to the other at an angle of 45°. (See Plate II for general form of orifices.)

These plates fitted in the lower central part of the partition of the orifice box. This partition was so constructed that it was water tight except for the orifice. Plate I gives the plan and end view of the orifice box.

Water was admitted into the tank through a 6-inch pipe, flowed through baffle boards into compartment A, then through the orifice into compartment B, and out through two vertical openings in the end of the box. From there an 8-inch galvanized iron pipe led to the measuring pit. The vertical openings were covered by baffle-boards which kept the water at any desired height. In these baffle-boards were holes in which corks were placed or removed according to the desire to decrease or increase the discharge. In experimenting with some of the small orifices it was found necessary to nail sacks around the boards in order to obtain a very small discharge.

The difference in level in the two compartments, which is known as the discharge head, or head causing the flow, was measured by means of two vertical glass tubes, one connected with one compartment, and the other connected with the second compartment, and fastened one on each side of a scale reading to millimeters as shown in Plate I.

The water discharged, was measured in a circular concrete pit 7.995 feet in diameter and about 6 feet deep. A float and level rod graduated to hundreds of a foot were used in measuring the rise in the pit.

A set of experiments consisted of readings taken with various effective heads, most of them being under 0.5 feet. In making these experiments the water was wasted until running at a steady head, then was measured for a period rangeing from 100 to 900 seconds, and wasted again.

III.

SOURCES OF ERROR.

The probable sources of error which arose are as follows:-

The diameter assumed for the pit is that used by Mr. C. C. Wiley ('04 University of Illinois) in his experiments. It was the means of thirty readings carefully taken. The largest variation from the means of these experiments was 0.008 feet. Hence, the maximum error will not be over 0.10%.

In measuring with the float and level rod the greatest variation in reading would not exceed .01 ft. Hence the maximum error would occur where the smallest rise in the pit (0.49 ft.) was recorded. This case would give a maximum error of 2.04%. This was an exceptionally low rise the average rise being about 1.00 ft. thus reducing the error to about 1.00%.

The water in the measuring tubes stood quite still as a rule and an effort was made to read the level to half a millimeter or .0016 ft. Therefore, with the smallest head (0.085 ft.) the maximum error would occur. This error would then be 1.88%. The average error from this source, however, would amount to a great deal less than this. For example, for a head of .225 ft. the error would be 0.71%.

All time measuiments were taken with an ordinary watch to the nearest second. The shifting of the pipe took about half a second, consequently the maximum error would occur when the shortest time 100 seconds was used. This would give a maximum error of 0.50%.

All of these maximum errors would not occur at the same time. Besides it is the square root of h and not h itself which occurs in the results so that the greatest error under low heads probably does not exceed 4.5%. In the later tests made, where the time was greater and the rise in pit larger, the total error would probably in no case exceed 1.25%.

IV.

EXPLANATION OF TABLES AND PLATES.

The tables and plates given are arranged as follows:-

Table I gives the general results of all the experiments made, including the readings taken and coefficients deduced.

Table 2 gives the values of the coefficients of discharge for the various orifices experimented with under different heads as taken from the curves.

Table 3 shows the velocity of the water flowing through the various orifices, under different heads.

Plate I shows a cross section and end view of the orifice box used throughout the experiments.

Plate II gives the general form of orifice plate used in the experiments, with dimensions.

Plate III contains photographs of the orifice box used, the measuring pit, and the general arrangement of the apparatus.

Plate IV to IX contain curves showing the relation between the coefficient of discharge (c) and the effective head (h) for the six different orifices. They also show curves plotted from values obtained by Hamilton Smith Jr. in 1884 for free discharge.

Plate X shows a comparison of the different coefficients of discharge for the different shaped orifices.

V.

DISCUSSION OF RESULTS AND CONCLUSSIONS.

From the data experimentally determined, the following conclussions may be drawn:-

(I) Of the two series of experiments performed on some of the orifices, the results of the second set are to be relied upon to a far greater extent than those of the first. This is due to the fact that the first series were performed with only a small rise of water in the measuring pit, while in the other set, a rise from two to three times as great was used. Consequently there was not such a probability of error and wide range of values for coefficients.

(2) The separate orifice curves contained in Plates IV to IX represent the most probable values of the coefficients of discharge for the submerged orifice.

(3) Without any exception the diagrams appear to be straight lines for heads of 0.2 ft. or over. For heads between 0.1 ft. and 0.2 ft. the rise in coefficients is very small, the extreme case being .004.

(4) The curves plotted on Plate X show that, the larger the opening in the orifice the smaller the coefficient of discharge. Thus there is a range of .013 between a 6-inch and a 2-inch circular orifice. For the square ones the same is true, there being a difference of .009 between a 2-inch and a 4-inch. From the one rectangular orifice experimented with it can be plainly seen that this orifice gives the

largest coefficients of discharge. This is shown by the fact that the principal contraction is on two sides of the orifice. The values obtained from this orifice were on an average of 1.62% higher than for orifices with a much smaller opening. Scarcely any difference is shown between the coefficients of a circular orifice and a square shaped orifice. This seems rather odd as we naturally expect a larger coefficient for the square than for the circular since there is less contraction on the former than on the latter.

(5) Coefficients of discharge for submerged orifices are undoubtedly larger than those for free discharge. A comparison of the curves on Plates IV to IX readily show this. The coefficients of discharge as determined from these experiments are from 1.67% to 0.55% larger than for free discharge through orifices of the same shape and size as determined by Hamilton Smith Jr. in 1884. In only one case are the values given here smaller than those for free discharge, that being for the 4-inch square orifice where the values for submergence are 0.49% less. This can only be accounted for by a constant error in determining the values for the 4-inch square, but even this seems hardly probable, as the results determined were more nearly constant than for any other orifice. A difference of 1.0% is probably a safe average for values of submerged and free discharging orifices.

Hamilton Smith Jr. has probably done the greatest amount of experimenting to date in this line, but in no case has he determined values for effective heads under 0.5 ft.

Work of this kind is very interesting and there is undoubtedly a great deal of work which may yet be done along this line.

1	2	3	4	5	6	7	8	9
Ref. No.	Kind of Orifice	Effective Head in Feet "h"	Time in Seconds	Rise in Pit Feet	Actual Discharge "q" Cu. Ft. per Sec	$Q = a\sqrt{2gh}$ Cu. Ft. per Sec.	Coef. of Discharge "c"	Average Actual Vel. Feet per Sec.
1	4-in.	0.156	147	0.49	0.168	0.275	0.609	1.94
2	Cir-	0.152	205	0.68	0.168	0.273	0.615	1.94
3	cular	0.150	210	0.71	0.170	0.275	0.618	1.96
4		0.144	170	0.55	0.163	0.266	0.611	1.87
5		0.153	140	0.46	0.166	0.274	0.608	1.91
6		0.172	180	0.64	0.178	0.290	0.612	2.05
7		0.212	185	0.72	0.195	0.319	0.611	2.24
8		0.274	180	0.81	0.225	0.365	0.617	2.60
9		0.375	170	0.88	0.259	0.429	0.602	2.98
10		0.375	270	1.41	0.260	0.429	0.606	3.00
11		0.384	135	0.71	0.264	0.431	0.611	3.04
12		0.392	140	0.74	0.265	0.434	0.616	3.05
13		0.509	170	1.03	0.303	0.498	0.609	3.49
14		0.521	140	0.85	0.305	0.504	0.604	3.50
15		0.514	200	1.21	0.302	0.500	0.607	3.48
16		0.512	220	1.35	0.307	0.501	0.612	3.54
17		0.626	125	0.82	0.329	0.548	0.600	3.78
18		0.639	135	0.92	0.340	0.556	0.611	3.90
19		0.770	130	0.95	0.369	0.612	0.602	4.25
20		0.990	100	0.85	0.425	0.700	0.608	4.89
21		1.144	120	1.10	0.458	0.749	0.612	5.27
22		1.220	150	1.40	0.470	0.775	0.609	5.41
23		1.220	165	1.55	0.472	0.774	0.610	5.43
24		1.306	150	1.44	0.481	0.800	0.602	5.53
25		0.760	155	1.16	0.375	0.608	0.618	4.31
26		0.286	120	0.54	0.224	0.370	0.602	2.56
27		0.426	125	0.70	0.280	0.455	0.616	3.22
28		1.610	110	1.20	0.545	0.890	0.612	6.27
29		0.275	165	0.75	0.222	0.367	0.604	2.55
30		0.274	160	0.70	0.220	0.366	0.602	2.52
31		0.910	115	0.95	0.415	0.671	0.619	4.76
32		1.322	150	1.49	0.500	0.812	0.618	5.73
33		0.501	210	1.27	0.305	0.495	0.618	3.50
34		0.508	180	1.10	0.307	0.499	0.617	3.54
35		0.209	405	1.56	0.192	0.319	0.601	2.20
36		0.210	480	1.85	0.193	0.320	0.601	2.21
37		0.211	425	1.65	0.194	0.321	0.603	2.22
38		0.212	445	1.74	0.195	0.321	0.605	2.23
39		0.126	420	1.26	0.150	0.248	0.608	1.73
40		0.113	480	1.38	0.144	0.236	0.611	1.66
41		0.137	600	1.89	0.158	0.259	0.610	1.82
42		0.147	360	1.17	0.163	0.269	0.609	1.87
43		0.241	420	1.77	0.210	0.345	0.610	2.41
44		0.230	420	1.73	0.205	0.336	0.609	2.35
45		0.221	420	1.68	0.200	0.329	0.609	2.30
46		1.202	220	2.04	0.463	0.764	0.607	5.31

1	2	3	4	5	6	7	8	9
47	4-in.	1.221	155	1.49	0.480	0.789	0.610	5.51
48	Cir-	0.983	200	1.70	0.425	0.699	0.609	4.89
49	cular.	0.925	205	1.69	0.411	0.677	0.610	4.74
50		1.120	220	2.00	0.454	0.745	0.610	5.21
51		1.065	200	1.77	0.442	0.726	0.610	5.09
52		0.496	270	1.63	0.300	0.493	0.610	3.45
53		0.508	300	1.81	0.301	0.496	0.608	3.46
54		0.510	260	1.58	0.305	0.500	0.610	3.51
55	6-in.	0.120	340	2.24	0.328	0.541	0.601	1.64
56	Cir-	0.118	250	1.61	0.324	0.539	0.600	1.66
57	cular.	0.120	300	1.95	0.326	0.542	0.600	1.65
58		0.120	240	1.57	0.328	0.542	0.601	1.64
59		0.146	240	1.73	0.360	0.599	0.600	1.83
60		0.145	260	1.85	0.356	0.594	0.599	1.82
61		0.148	265	1.92	0.363	0.600	0.600	1.84
62		0.275	180	1.77	0.494	0.811	0.599	2.51
63		0.275	205	2.01	0.494	0.811	0.599	2.51
64		0.276	170	1.68	0.496	0.811	0.601	2.52
65		0.258	230	2.19	0.475	0.796	0.599	2.42
66		0.444	270	3.38	0.624	1.043	0.598	3.18
67		0.447	260	3.25	0.625	1.043	0.597	3.18
68		0.436	240	2.99	0.621	1.038	0.600	3.15
69		0.441	210	2.61	0.622	1.041	0.598	3.16
70		0.711	220	3.48	0.790	1.320	0.598	4.02
71		0.711	205	3.24	0.790	1.320	0.598	4.02
72		0.713	220	3.49	0.792	1.322	0.599	4.02
73	2-in.	0.338	540	0.67	0.062	0.101	0.612	2.85
74	Cir-	0.343	480	0.59	0.062	0.102	0.605	2.85
75	cular.	0.345	600	0.75	0.063	0.102	0.614	2.90
76		0.354	690	0.88	0.064	0.104	0.617	2.95
77		0.588	420	0.69	0.082	0.134	0.618	3.80
78		0.580	540	0.88	0.082	0.133	0.615	3.80
79		0.581	420	0.68	0.081	0.132	0.612	3.73
80		0.594	600	0.99	0.083	0.135	0.615	3.82
81		0.178	720	0.65	0.045	0.073	0.618	2.07
82		0.178	580	0.52	0.045	0.073	0.615	2.07
83		0.181	900	0.81	0.045	0.074	0.611	2.07
84		0.188	960	0.89	0.046	0.075	0.618	2.12
85		0.123	840	0.62	0.037	0.061	0.612	1.70
86		0.127	900	0.68	0.038	0.061	0.611	1.75
87		0.124	810	0.62	0.038	0.062	0.620	1.75
88		0.124	960	0.72	0.038	0.062	0.614	1.75
89		0.760	480	0.89	0.093	0.151	0.612	4.28
90		0.743	480	0.88	0.092	0.150	0.610	4.24
91		0.720	540	0.97	0.090	0.147	0.611	4.14
92		0.713	520	0.94	0.090	0.147	0.612	4.14
93		1.049	300	0.66	0.110	0.179	0.616	5.04
94		1.081	390	0.87	0.112	0.181	0.615	5.17
95		1.082	300	0.66	0.111	0.181	0.612	5.11

1	2	3	4	5	6	7	8	9
96	2-in.	1.081	310	0.69	0.111	0.182	0.611	5.11
97	Cir-	1.080	330	0.73	0.111	0.182	0.611	5.11
98	cular	1.460	310	0.79	0.128	0.210	0.610	5.89
99		1.424	360	0.92	0.128	0.208	0.614	5.89
100		1.426	305	0.78	0.128	0.208	0.613	5.89
101		1.422	420	1.07	0.128	0.207	0.612	5.89
102	2-in.	1.687	290	1.02	0.176	0.289	0.610	6.33
103	square	1.659	420	1.47	0.175	0.287	0.610	6.30
104	7	1.661	285	1.00	0.175	0.287	0.610	6.30
105		1.683	330	1.15	0.175	0.286	0.608	6.30
106		1.038	390	1.07	0.138	0.227	0.609	4.97
107	6	1.022	360	0.99	0.138	0.229	0.611	4.97
108		1.007	360	0.97	0.136	0.224	0.609	4.88
109		0.990	420	1.14	0.136	0.221	0.612	4.88
110		0.670	420	0.95	0.113	0.182	0.620	4.07
111		0.679	360	0.79	0.110	0.183	0.601	3.95
112		0.682	360	0.80	0.111	0.184	0.604	3.98
113	5	0.684	360	0.79	0.110	0.183	0.600	3.95
114		0.697	605	1.37	0.113	0.185	0.610	4.88
115		0.700	540	1.22	0.113	0.186	0.609	4.88
116		0.709	480	1.10	0.114	0.187	0.611	4.10
117		0.112	900	0.82	0.045	0.073	0.612	1.62
118		0.114	720	0.66	0.046	0.075	0.611	1.65
119	1	0.113	660	0.60	0.045	0.073	0.613	1.62
120		0.112	660	0.59	0.045	0.074	0.608	1.62
121		0.112	720	0.65	0.045	0.074	0.610	1.62
122		0.165	600	0.66	0.055	0.090	0.609	1.98
123		0.164	600	0.66	0.055	0.091	0.610	1.98
124	2	0.164	660	0.71	0.054	0.090	0.602	1.96
125		0.164	765	0.84	0.055	0.090	0.609	1.98
126		0.332	480	0.75	0.078	0.128	0.610	2.81
127		0.336	540	0.85	0.079	0.130	0.610	2.84
128	3	0.336	540	0.85	0.079	0.130	0.610	2.84
129		0.335	480	0.75	0.078	0.128	0.609	2.81
130		0.501	360	0.69	0.096	0.158	0.610	3.46
131	4	0.504	420	0.80	0.096	0.159	0.607	3.46
132		0.512	445	0.87	0.098	0.160	0.612	3.53
133		0.520	280	0.54	0.097	0.161	0.604	3.49
134	4-in.	0.089	480	1.53	0.160	0.264	0.604	1.44
135	square	0.086	540	1.70	0.158	0.260	0.605	1.43
136		0.086	495	1.54	0.157	0.260	0.602	1.43
137		0.085	520	1.62	0.157	0.261	0.603	1.43
138		0.164	170	0.73	0.215	0.356	0.601	1.94
139		0.163	120	0.52	0.216	0.356	0.600	1.95
140		0.163	190	0.82	0.216	0.356	0.604	1.95
141		0.213	160	0.79	0.247	0.409	0.603	2.24
142		0.218	100	0.49	0.246	0.415	0.597	2.22
143		0.219	120	0.60	0.250	0.415	0.602	2.25
144		0.215	120	0.60	0.250	0.412	0.605	2.25
145		0.174	150	0.67	0.224	0.369	0.603	2.01
146		0.166	120	0.52	0.218	0.360	0.604	1.96
147		0.166	140	0.61	0.219	0.361	0.603	1.97

1	2	3	4	5	6	7	8	9
148	4-in.	0.164	125	0.54	0.217	0.359	0.602	1.96
149	square	0.350	155	0.98	0.315	0.525	0.600	2.85
150		0.355	175	1.11	0.316	0.528	0.601	2.85
151		0.315	155	0.93	0.300	0.497	0.602	2.70
152		0.314	195	1.16	0.299	0.498	0.600	2.70
153		0.627	140	1.18	0.423	0.705	0.600	3.80
154		0.622	155	1.30	0.420	0.699	0.599	3.75
155		0.626	170	1.43	0.420	0.702	0.598	3.79
156		0.608	300	2.50	0.416	0.691	0.601	3.76
157		0.573	240	1.94	0.405	0.673	0.601	3.55
158		0.607	270	2.25	0.416	0.690	0.601	3.76
159		0.609	185	1.55	0.419	0.695	0.602	3.71
160		0.109	480	1.68	0.176	0.294	0.600	1.59
161		0.109	480	1.68	0.176	0.294	0.600	1.59
162		0.153	450	1.87	0.208	0.347	0.600	1.88
163		0.152	425	1.77	0.209	0.346	0.601	1.88
164		0.146	420	1.71	0.205	0.341	0.600	1.85
165		0.149	420	1.73	0.206	0.343	0.601	1.86
166		0.335	270	1.67	0.310	0.514	0.602	2.80
167		0.338	295	1.82	0.310	0.517	0.600	2.80
168		1.068	280	3.10	0.553	0.920	0.602	5.00
169		1.077	260	2.88	0.555	0.921	0.602	5.01
170		1.096	280	3.13	0.561	0.930	0.601	5.08
171	6-in. x	0.110	635	0.88	0.069	0.110	0.627	1.66
172	1-in.	0.110	600	0.82	0.069	0.111	0.621	1.66
173	Rect.	0.110	780	1.07	0.069	0.111	0.620	1.66
174		0.108	705	0.97	0.069	0.110	0.629	1.66
175		0.108	505	0.69	0.069	0.110	0.630	1.66
176		0.157	410	0.67	0.082	0.131	0.622	1.96
177		0.156	660	1.09	0,083	0.132	0.629	1.99
178		0.152	540	0.89	0.083	0.132	0.632	1.99
179		0.154	680	1.11	0.082	0.131	0.624	1.96
180		0.153	595	0.98	0.083	0.131	0.631	1.99
181		0.254	500	1.05	0.105	0.169	0.621	2.51
182		0.248	480	0.99	0.104	0.167	0.622	2.49
183		0.257	600	1.25	0.104	0.168	0.619	2.49
184		0.256	620	1.30	0.105	0.169	0.621	2.51
185		0.345	420	1.03	0.123	0.197	0.627	2.95
186		0.344	630	1.54	0.122	0.196	0.623	2.97
187		0.331	480	1.15	0.120	0.192	0.624	2.87
188		0.334	395	0.95	0.120	0.193	0.622	2.87
189		0.334	540	1.30	0.120	0.193	0.622	2.87
190		0.620	315	1.03	0.164	0.264	0.622	3.92
191		0.631	555	1.82	0.164	0.265	0.620	3.82
192		0.620	300	0.98	0.163	0.260	0.621	3.90
193		0.611	350	1.14	0.164	0.261	0.627	3.92
194		0.981	300	1.22	0.204	0.330	0.619	4.87
195		0.989	345	1.43	0.206	0.329	0.626	4.95
196		0.992	480	1.99	0.207	0.332	0.622	4.97
197		0.990	270	1.12	0.208	0.335	0.628	4.98
198		1.617	240	1.25	0.260	0.423	0.617	6.23
199		1.606	250	1.33	0.270	0.432	0.629	6.49
200		1.608	330	1.75	0.270	0.432	0.624	6.49

TABLE 2

COEFFICIENTS OF DISCHARGE DETERMINED

FOR

SUBMERGED ORIFICES

FROM

CURVES.

Effective Head h in Feet	Kind of Orifice.					
	2-in. Circular	4-in. Circular	6-in. Circular	2-in. Square	4-in. Square	6in x 1-in Rect.
0.10	0.614	0.609	0.601	0.611	0.603	0.625
0.15	0.614	0.609	0.600	0.611	0.601	0.624
0.20	0.613	0.609	0.599	0.610	0.601	0.623
0.30	0.613	0.609	0.599	0.610	0.601	0.622
0.40	0.613	0.609	0.599	0.610	0.601	0.622
0.50	0.613	0.609	0.599	0.610	0.601	0.622
0.75	0.613	0.609	0.599	0.610	0.601	0.622
1.00	0.613	0.609		0.610	0.601	0.622
1.50	0.613	0.609		0.610		0.622
2.00	0.613			0.610		0.622

TABLE 3

AVERAGE VELOCITY OF WATER

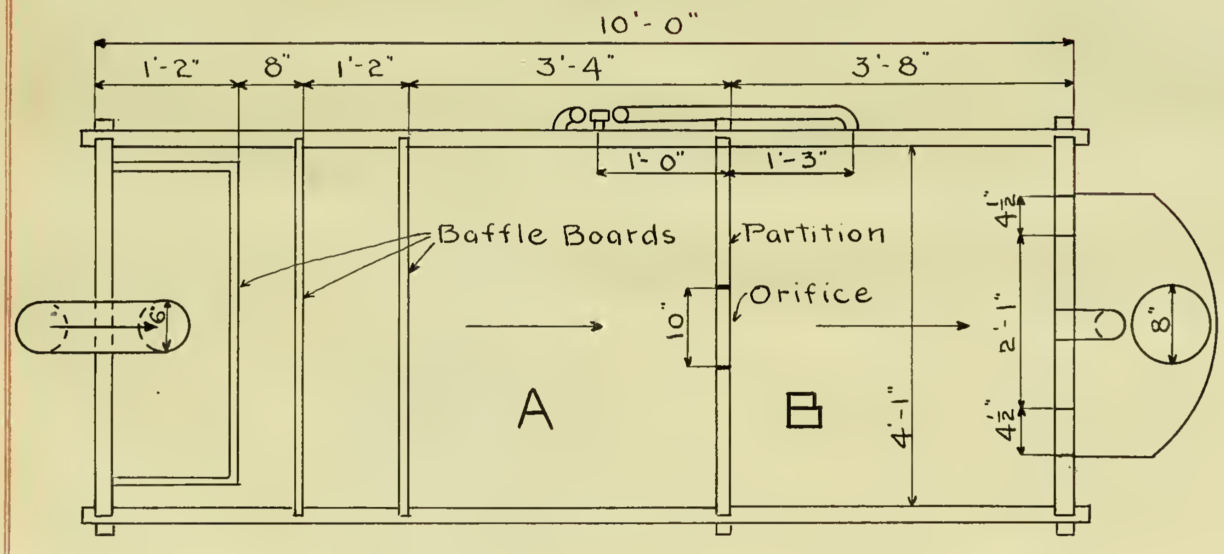
THROUGH SUBMERGED ORIFICES

IN

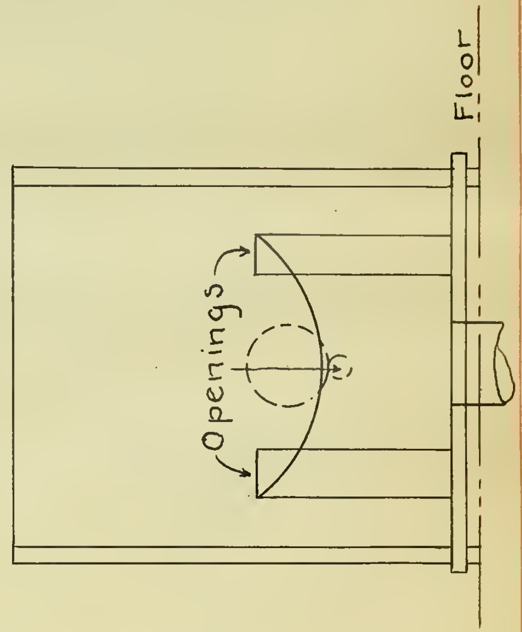
FEET PER SECOND.

Effective Head h in Feet.	Kind Of Orifice.					
	2-in. Circular	4-in. Circular	6-in. Circular	2-in. Square	4-in. Square	6-in x 1-in Rect.
0.10	1.61	1.60	1.53	1.58	1.56	1.60
0.15	1.87	1.90	1.85	1.80	1.82	1.92
0.20	2.15	2.20	2.10	2.19	2.18	2.25
0.30	2.92	2.70	2.68	2.66	2.61	2.72
0.40	3.01	3.02	2.96	2.99	2.97	3.08
0.50	3.40	3.48	3.46	3.46	3.50	3.42
0.75	4.25	4.21	4.06	4.08	4.17	4.29
1.00	5.01	4.90		4.92	4.93	4.98
1.50	5.92	6.21		6.18		6.29

PLATE I
PLAN AND END VIEW OF ORIFICE BOX



PLAN



END VIEW

PLATE II
TYPICAL ORIFICE PLATES

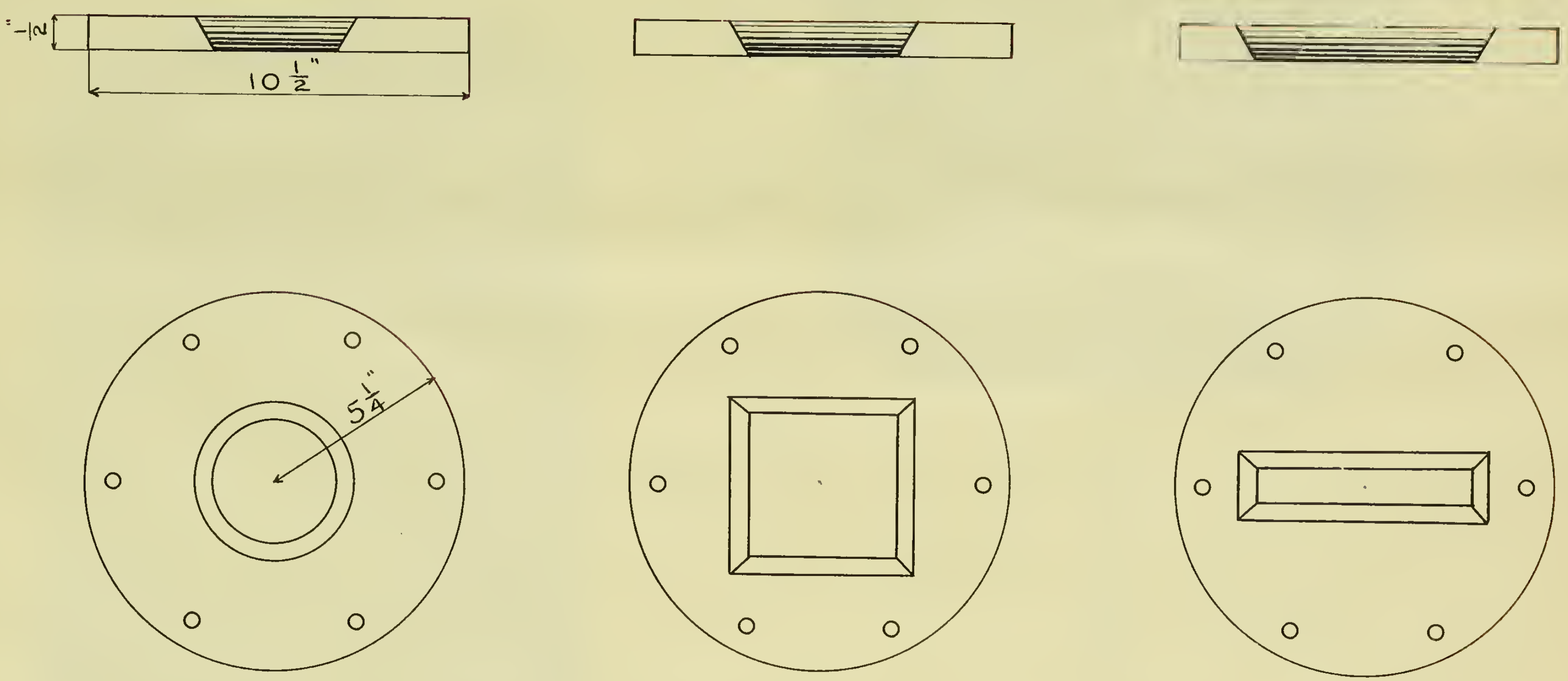
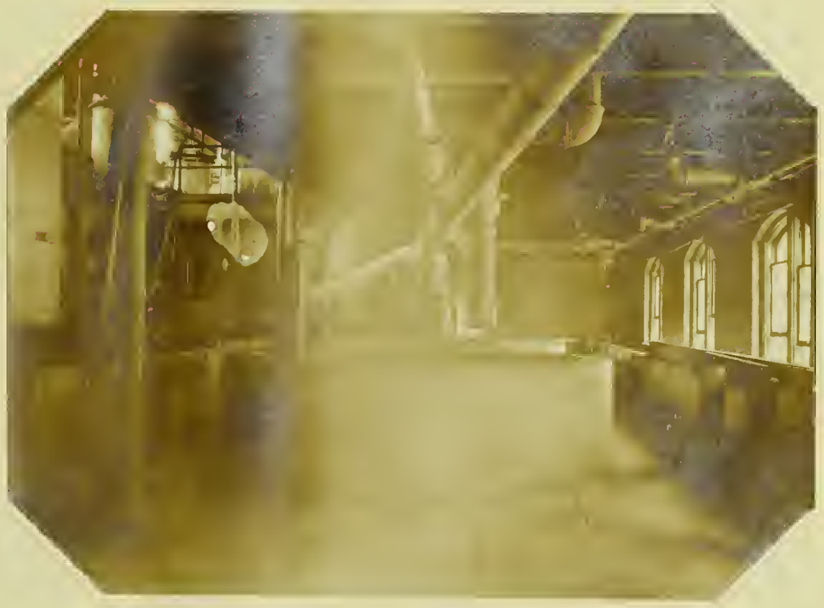


PLATE III

ORIFICE BOX

MEASURING PIT



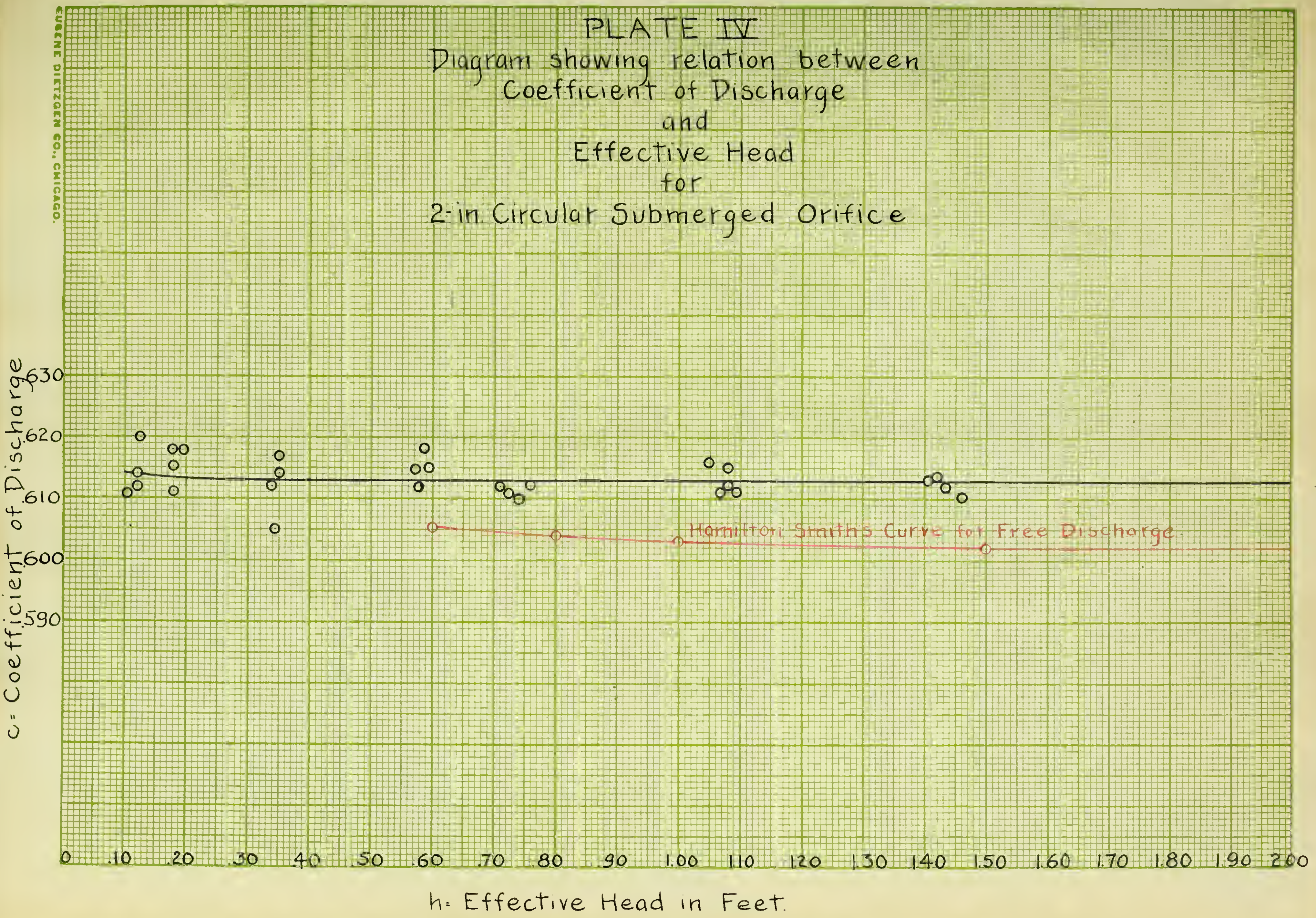


PLATE IV
Diagram showing relation between
Coefficient of Discharge
and
Effective Head
for
2-in. Circular Submerged Orifice
Hamilton Smith's Curve for Free Discharge
.630
.620
.610
.600
.590
c = Coefficient of Discharge
0
.10
.20
.30
.40
.50
.60
.70
.80
.90
1.00
1.10
1.20
1.30
1.40
1.50
1.60
1.70
1.80
1.90
2.00
h = Effective Head in Feet
EUGENE DIETZGEN CO., CHICAGO.

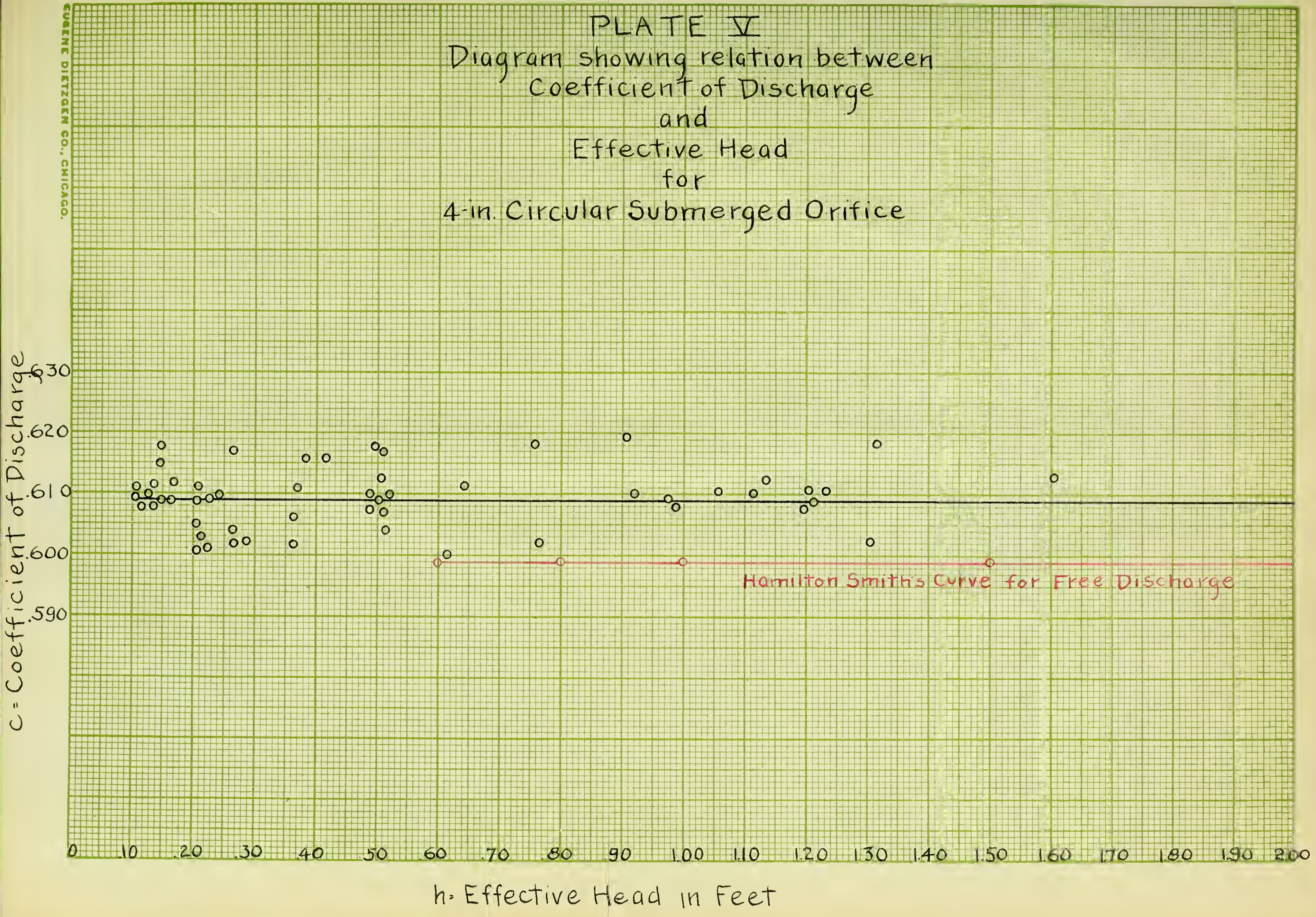


PLATE V
Diagram showing relation between
Coefficient of Discharge
and
Effective Head
for
4-in. Circular Submerged Orifice
Hamilton Smith's Curve for Free Discharge
c = Coefficient of Discharge
.630
.620
.610
.600
.590
0
.10
.20
.30
.40
.50
.60
.70
.80
.90
1.00
1.10
1.20
1.30
1.40
1.50
1.60
1.70
1.80
1.90
2.00
h = Effective Head in Feet
EUGENE DIETZGEN CO., CHICAGO.

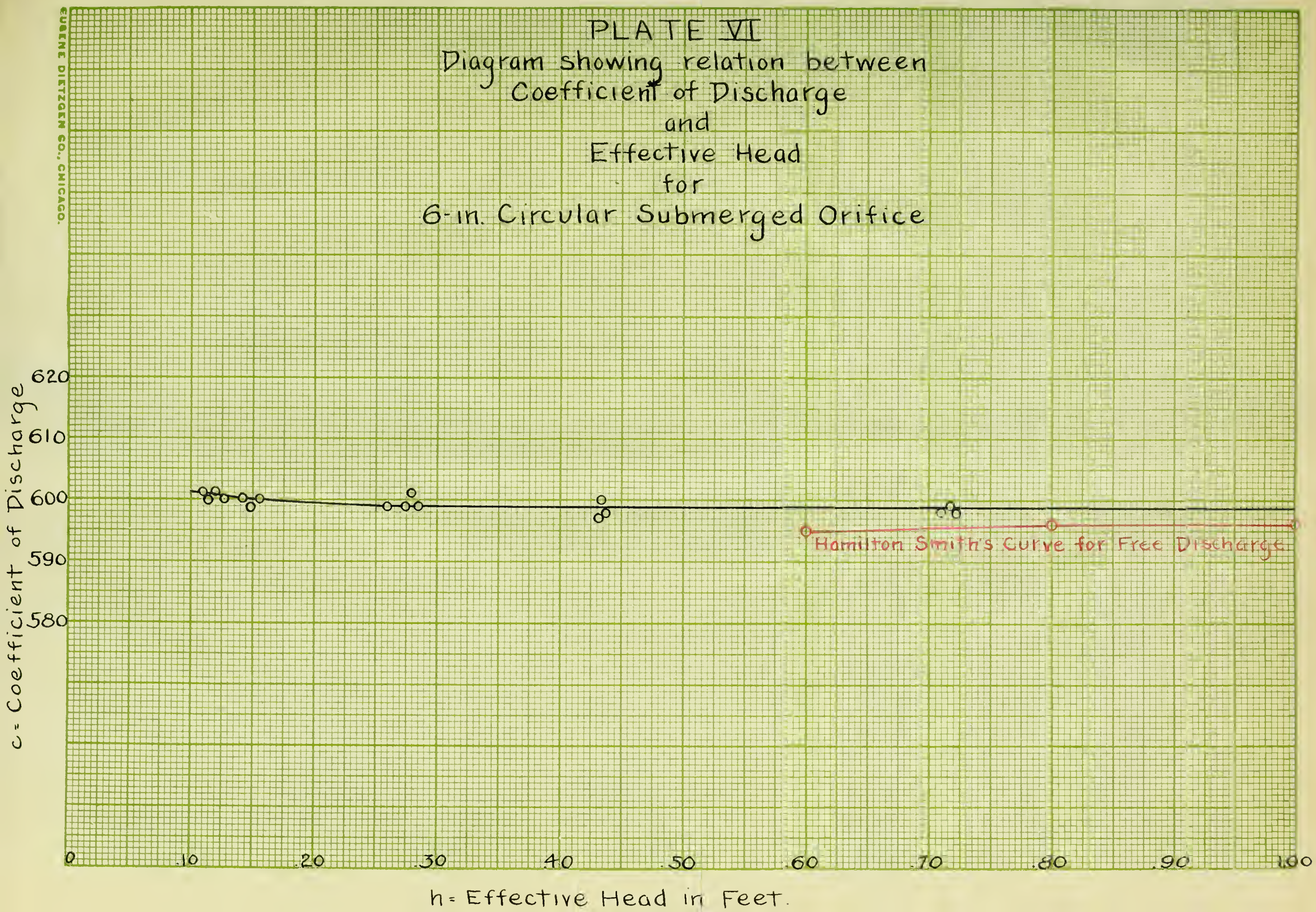


PLATE VI
Diagram showing relation between
Coefficient of Discharge
and
Effective Head
for
6-in. Circular Submerged Orifice
620
610
600
590
580
c = Coefficient of Discharge
0
.10
.20
.30
.40
.50
.60
.70
.80
.90
1.00
h = Effective Head in Feet.
Hamilton Smith's Curve for Free Discharge
EUGENE DIETZGEN CO., CHICAGO.

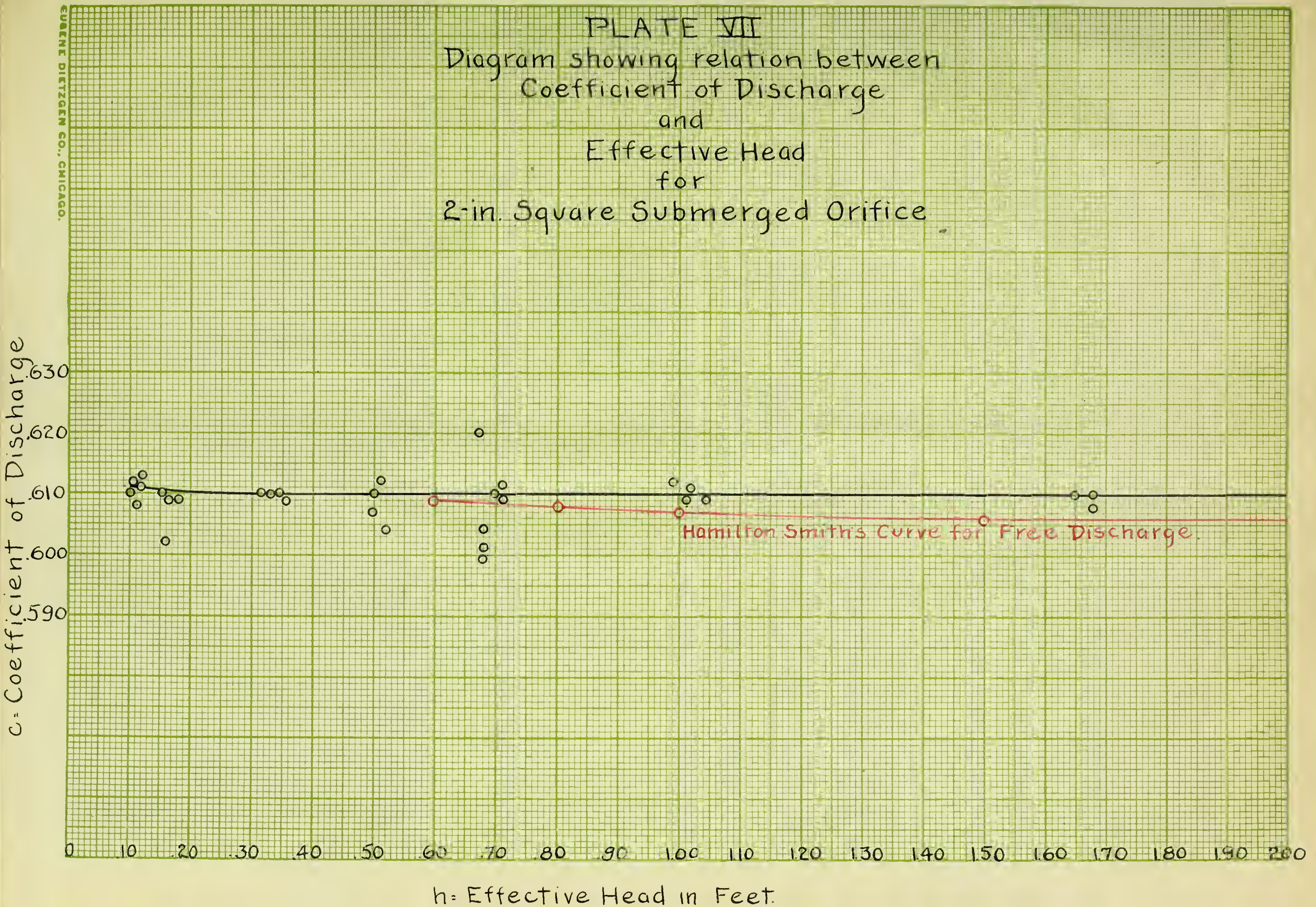


PLATE VII
Diagram showing relation between
Coefficient of Discharge
and
Effective Head
for
2-in. Square Submerged Orifice
EUGENE DIETZGEN CO., CHICAGO.
c = Coefficient of Discharge
.630
.620
.610
.600
.590
Hamilton Smith's Curve for Free Discharge
0
.10
.20
.30
.40
.50
.60
.70
.80
.90
1.00
1.10
1.20
1.30
1.40
1.50
1.60
1.70
1.80
1.90
2.00
h = Effective Head in Feet

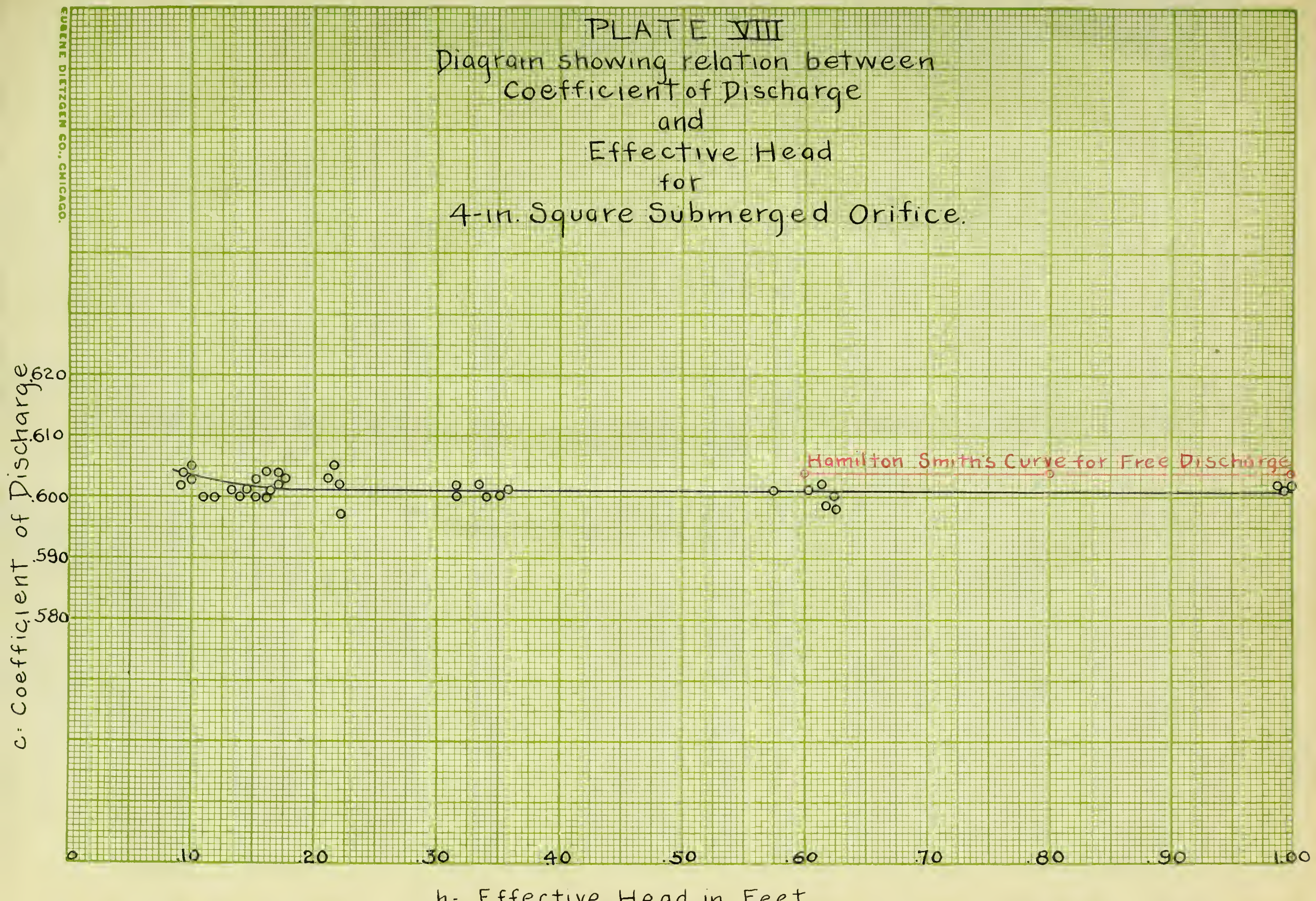


PLATE VIII
Diagram showing relation between
Coefficient of Discharge
and
Effective Head
for
4-in. Square Submerged Orifice.
EUGENE DIETZGEN CO., CHICAGO.
Hamilton Smith's Curve for Free Discharge
c = Coefficient of Discharge
.620
.610
.600
.590
.580
0
.10
.20
.30
.40
.50
.60
.70
.80
.90
1.00
h = Effective Head in Feet

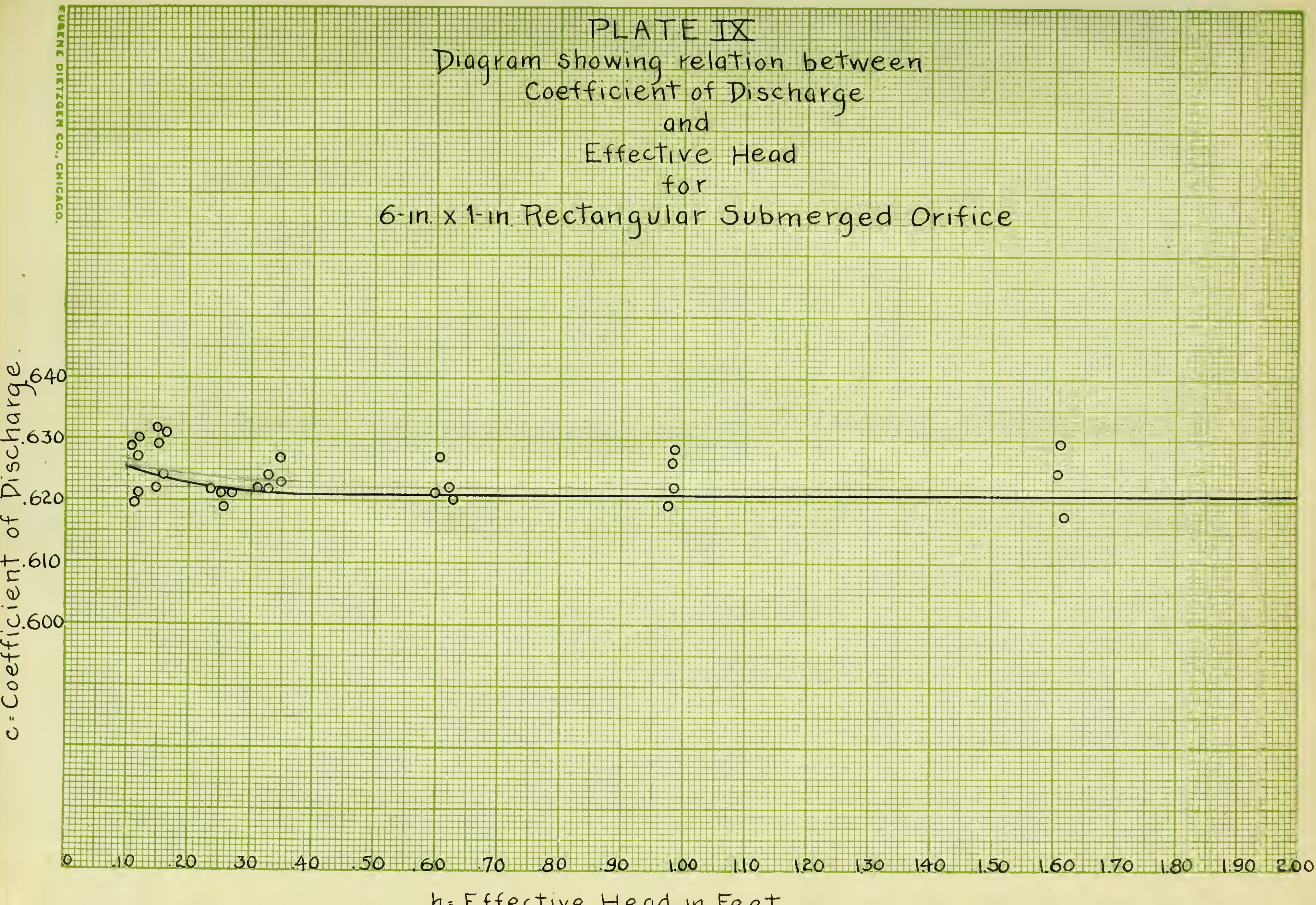


PLATE IX
Diagram showing relation between
Coefficient of Discharge
and
Effective Head
for
6-in. x 1-in. Rectangular Submerged Orifice
c = Coefficient of Discharge.
.640
.630
.620
.610
.600
0
.10
.20
.30
.40
.50
.60
.70
.80
.90
1.00
1.10
1.20
1.30
1.40
1.50
1.60
1.70
1.80
1.90
2.00
h = Effective Head in Feet
EUGENE DIETZGEN CO., CHICAGO.

PLATE X

Diagram showing relation between
Submerged Orifices of Different Shapes
and their
Coefficients of Discharge